BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

SUBJECT: An Evaluation of the Concept of Crew Member Radiation Standards - Case 340

DATE: September 30, 1968

FROM: R. H. Hilberg
R. K. White

ABSTRACT

The MSC Radiation Constraint Panel is currently exploring the utility of the concept of crew member radiation standards for the Apollo lunar landing mission. The preliminary mission rules specify that the POD for the CSM pilot will be 1/2 the POD for the LM crew.

Some practical aspects of this concept are evaluated in this report, and some modifications are suggested in the light of this evaluation.

(NASA-CR-92641) AN EVALUATION OF THE CONCEPT OF CREW MEMBER RADIATION STANDARDS (Bellcomm, Inc.) 8 p

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MEMORANDUM FOR FILE

INTRODUCTION

The MSC Radiation Constraints Panel has the responsibility of tailoring a radiation program which is specific to each manned space flight. This responsibility is not in the narrow sense of picking appropriate values for dose limits, but entails the development of the conceptual framework required for reconciling the various constraints on the mission, of which radiation is only one. The final product of the RCP will be a set of mission rules which will formally describe alternate missions to be undertaken in the case that the adopted radiation dose limits are exceeded.

The minutes of the RCP, dated October 13, 1967, of the third meeting of the panel contain in Enclosure 3 a preliminary set of ground rules which are currently being evaluated by the RCP. (See the Appendix.) Rules 2, 5, and 6 of this set invoke the concept of "crew member" radiation standards. This concept is an innovation of the RCP and is an interesting variation on accepted health physics principles. The purpose of this paper is to evaluate the practical aspects of this concept.

THE CREW MEMBER RADIATION STANDARDS CONCEPT

The crew member radiation standards concept starts with the recognition of the fact that the role of each crew member is not equally critical in all phases of the mission for the success of that phase. In particular, on the return from the moon, the LM crew will play a minor role compared to the CM pilot. The obvious implication is that the pilot's physical well being is most critical in this phase. By this time in the mission he should not have been permitted to accumulate a radiation dose which may be permissible for the LM crew. Hence rule 2. The LM crew's being nauseous during this phase of the mission will entail less risk to mission success than the same symptons in the CM pilot.

PRACTICAL ASPECT OF THE CONCEPT

Without raising any issue about the derivation of these rules, let us consider the operational feasibility of this concept. Is it physically possible for the CM pilot and the LM crew to get significantly different depth dose?

Dose calculations have been performed for the astronauts in the Command Module in free space and in the Lunar Module and space suit on the lunar surface. The spectrum was assumed to be exponential in rigidity, with equal numbers of protons and alpha particles. The shield models used for the CM and LM are shown in Figure 1.* The spacesuit was taken to be 0.2g/cm^2 thick. Doses calculated in the LM and spacesuit were reduced by a factor of two to include shielding provided by the moon.

The results are shown in Table 1 for spectra with characteristic rigidities of 40 MV, 100 MV and 160 MV representing soft, average, and hard spectra. Because of the fact that several parameters are required to specify the number and spectrum of the particles in an event, it is not always meaningful to compare doses resulting from different spectra while holding the total number of particles fixed. Therefore the results of the calculations for the two shielding configurations should be compared for the same spectrum rather than for different spectra. Since an arbitrary scale factor is used for the total number of particles in this illustration the relative values are important rather than the absolute values. However this number was chosen to represent a very large event.

The uncertainty in any of the values calculated is probably not greater than a factor of 2 given the particle spectrum used. In an operational situation where the spectrum is never known perfectly the uncertainty in the dose prediction will be largely that in the estimates of the event size parameters. Even after the event is over the uncertainty in the overall particle flux is probably larger than a factor of two, while during the event the flux predictions are significantly less accurate. These facts imply that operationally the expected dose in one mission configuration must differ from that in an alternate configuration by more than a factor of two before one can justify selecting one made over the other.

It is seen from Table 1 that the skin dose is the only tissue dose that can be reduced appreciably by modifying the mission during its lunar phases. Of course other doses accumulated up to the time of some particular maneuver may be affected by early mission modification, but with the above

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*Alva C. Hardy, MSC; personal communication.

shield model and spectra it turns out that the total depth doses are relatively insensitive to whether the astronaut is in the LM on the moon or in the CM. In fact, because of the shielding provided by the moon, in some cases the depth dose is lower in the LM on the lunar surface than in the CM. Therefore it appears that at this phase of the mission the only total tissue dose which mission rules can affect is that producing erythema.

CONCLUSIONS

The above calculations show that with regard to total accumulated dose the only tissue dose that can be affected significantly by mission rules during the lunar phase of the mission is the skin dose. However, when a mission operation imposes a requirement for crew performance at some particular part of the mission, the rules can reduce the dose accumulated up to that time by moving that phase of the mission forward in time with some mission alteration.

It is suggested that in rule 2 the GI dose criteria which cannot really be enforced be replaced by skin dose limits which mission rules can affect.

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GROUND RULES FOR LUNAR MISSION RADIATION

1. A COUNTDOWN RADIATION ANALYSIS PREDICTION OF DOSE TO THE CREW OVER THE NOMINAL LUNAR MISSION SHALL BE MADE AT T-28 HRS IN THE COUNTDOWN. THIS PREDICTION WILL BE BASED ON DATA FROM CURRENT MEASUREMENTS AND EXPECTED SOLAR ACTIVITY OVER THE TIME SPAN OF THE MISSION.

2. A POD FOR EACH CREW MEMBER WILL BE THE BASIS FOR ANY DECISION REGARDING THE PREDICTED DOSES. POD - LM CREW - DEPTH DOSE FOR 10% NAUSEA.
   - CSM PILOT - 1/2 DEPTH DOSE FOR 10% NAUSEA.

3. PREDICTED SOLAR ACTIVITY SHOULD INFLUENCE THIS DECISION ONLY WHEN:

   A. CURRENT MEASUREMENTS LEAVE A NARROW MARGIN BETWEEN PROJECTED DOSE AND POD.
   B. A SOLAR FLARE IS OCCURRING.

4. THE POD SHOULD BE APPLICABLE ONLY DURING THE COUNTDOWN PHASE. THE MOD WILL BE APPLICABLE THEREAFTER.

5. ONE LIMIT CAN BE SPECIFIED FOR THE CM PILOT OVER THE ENTIRE MISSION. (1/2 THE DOSE NEEDED TO PRODUCE 10 PERCENT NAUSEA).

6. THE LIMIT FOR THE LM CREW MAY VARY FOR DIFFERENT PHASES.

7. ASSUME THAT A SOLAR FLARE PROTON EVENT CAN OCCUR WITHOUT CONSIDERATION TO PROBABILITIES.

8. ASSUME THAT EXCEEDING THE SPECIFIED DOSE LIMIT WILL RESULT IN THE EXPECTED BIOLOGICAL EFFECT.

9. THE CREWS EVALUATION OF THEIR OWN PHYSICAL CONDITION AS WELL AS ACCUMULATED DOSE WILL BE CONSIDERED IN THE PLANNING FOR THE REMAINING MISSION OBJECTIVES.

GROUND RULES FOR LUNAR MISSION RADIATION (CONCLUDED)

10. A RADIATION ENVIRONMENT EVALUATION WILL BE REQUIRED PRIOR TO FINAL PREPARATION FOR THE LM CONFIDENCE INSPECTION.

    THIS EVALUATION WILL BE BASED ON THE TOTAL RADIATION ACCUMULATED THUS FAR IN THE MISSION PLUS THE CURRENT MEASURED DOSE RATE EXTRAPOLATED TO COVER THE TIME SPAN REQUIRED FOR THE LM CONFIDENCE INSPECTION.

11. A RADIATION ENVIRONMENT EVALUATION WILL BE REQUIRED PRIOR TO FINAL PREPARATION FOR THE LM SEPARATION AND DESCENT PHASE.

    THIS EVALUATION WILL BE BASED ON THE TOTAL RADIATION ACCUMULATED THUS FAR IN THE MISSION PLUS THE CURRENT MEASURED DOSE RATE EXTRAPOLATED TO COVER THE TIME SPAN OF LM INGRESS THROUGH LUNAR STAY TO DOCKING AND LM EGRESS.

    THIS EVALUATION WILL BE UPDATED PRIOR TO EVA AFTER LUNAR LANDING.

12. DOSE PROJECTION WILL BE MADE FOR EACH CREW MEMBER.

13. IN EACH EVALUATION THE RADIATION THROUGH THE REMAINDER OF THE MISSION WILL BE CONSIDERED WITHIN THE TOTAL DOSE LIMIT CONSTRAINTS.

TABLE 1 SOLAR PARTICLE DOSES

$N(>E) = 10^{10} e^{-P/P_o}$ protons or alpha particles/CM^2

DOSES (RAD)

Body Region	CM			LM + SS		
	$P_o = 40$	$P_o = 100$	$P_o = 160$	$P_o = 40$	$P_o = 100$	$P_o = 160$
Skin	.17	21	93	11	200	460
Blood Forming Organs	.006	5.3	34	.02	6	32
Gastrointestinal Tract	.0004	1.0	18	.0006	1.5	12

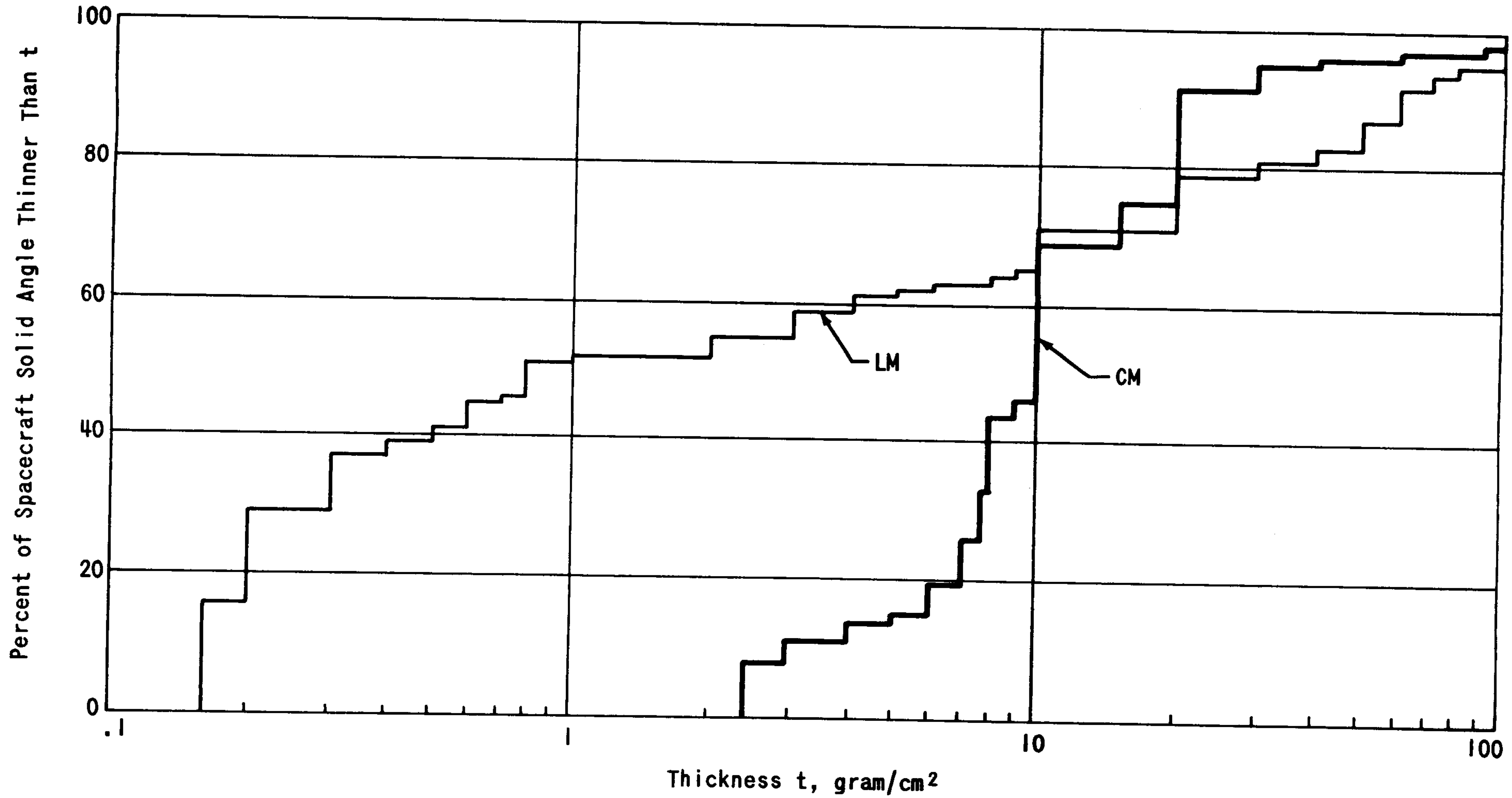

FIGURE 1 - SHIELDING OF CM AND LM